EE6621: COMPUTATIONAL PHYSIOLOGY AND NEURAL SYSTEMS

Effective Term

Semester B 2024/25

Part I Course Overview

Course Title

Computational Physiology and Neural Systems

Subject Code

EE - Electrical Engineering

Course Number

6621

Academic Unit

Electrical Engineering (EE)

College/School

College of Engineering (EG)

Course Duration

One Semester

Credit Units

3

Level

P5, P6 - Postgraduate Degree

Medium of Instruction

English

Medium of Assessment

English

Prerequisites

Nil

Precursors

Nil

Equivalent Courses

Nil

Exclusive Courses

BME6122 Physiological Modeling,
BME8133 Physiological Modeling

Part II Course Details

Abstract

This course explores the application of engineering principles to modeling in physiology and neuroscience, leveraging computing as a tool to better understand human body and the brain. It covers signal processing, control systems, and circuit theory for modeling complex biological processes, progressing from foundational physiology concepts to specialized topics in neural systems. Areas include advanced mathematical and computational methods, electrical analogs in physiological systems, feedback control in physiology, neuronal circuit modeling, bioelectric signal analysis, sensory system modeling, large-scale brain modeling, and neuromuscular system integration. Emphasis is placed on translating physiological concepts into quantitative frameworks, implementing models using computational tools familiar to engineers, and critically analyzing model predictions. Students will engage with current research literature and apply knowledge to construct, analyze, and interpret models of physiological and neural systems. This course prepares students for research and innovation in engineering applications such as wearables, human-computer interaction, biomedical instrumentation, and AI-driven healthcare technologies.

Course Intended Learning Outcomes (CILOs)

	CILOs	Weighting (if app.)	DEC-A1	DEC-A2	DEC-A3
1	Develop and implement models of physiological and neural systems using engineering principles		x	x	x
2	Apply signal processing techniques to analyze bioelectric signals, and basic machine learning algorithms for pattern recognition and classification of physiological data.			x	x
3	Analyze feedback mechanisms in physiological systems using control theory principles			x	x
4	Critically evaluate current research in computational neuroscience and physiology, applying this knowledge to interpret and refine models of complex biological systems		x	x	x

A1: Attitude
Develop an attitude of discovery/innovation/creativity, as demonstrated by students possessing a strong sense of curiosity, asking questions actively, challenging assumptions or engaging in inquiry together with teachers.

A2: Ability
Develop the ability/skill needed to discover/innovate/create, as demonstrated by students possessing critical thinking skills to assess ideas, acquiring research skills, synthesizing knowledge across disciplines or applying academic knowledge to real-life problems.

A3: Accomplishments
Demonstrate accomplishment of discovery/innovation/creativity through producing /constructing creative works/new artefacts, effective solutions to real-life problems or new processes.

Learning and Teaching Activities (LTAs)

	LTAs	Brief Description	CILO No.	Hours/week (if applicable)
1	Lectures	Interactive presentations that incorporate theoretical concepts with real-world examples	1, 2, 3, 4	

2	Case Study Analyses	Guided examinations of real physiological datasets or research papers, where students critically analyze data, evaluate existing models, and develop their own computational solutions using signal processing and machine learning techniques.	1, 2, 3, 4	
3	Project	Develop and present a computational model of a physiological or neural system, applying course concepts to solve a real-world problem.	1, 2, 3, 4	

Assessment Tasks / Activities (ATs)

	ATs	CILO No.	Weighting (%)	Remarks (e.g. Parameter for GenAI use)
1	Assignments	1, 2, 3, 4	10	
2	Project	1, 2, 3, 4	15	
3	Test	1	25	

Continuous Assessment (%)

50

Examination (%)

50

Examination Duration (Hours)

2

Additional Information for ATs

Remark:
To pass the course, students are required to achieve at least 30% in course work and 30% in the examination.

Assessment Rubrics (AR)

Assessment Task

Examination (for students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion

Achievements in CILOs

Excellent

(A+, A, A-) High

Good

(B+, B, B-) Significant

Fair

(C+, C, C-) Moderate

Marginal

(D) Basic

Failure
(F) Not even reaching marginal levels

Assessment Task
Coursework (for students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion
Achievements in CILOs

Excellent
(A+, A, A-) High

Good
(B+, B, B-) Significant

Fair
(C+, C, C-) Moderate

Marginal
(D) Basic

Failure
(F) Not even reaching marginal levels

Assessment Task
Examination (for students admitted from Semester A 2022/23 to Summer Term 2024)

Criterion
Achievements in CILOs

Excellent
(A+, A, A-) High

Good
(B+, B) Significant

Marginal
(B-, C+, C) Basic

Failure
(F) Not even reaching marginal levels

Assessment Task
Coursework (for students admitted from Semester A 2022/23 to Summer Term 2024)

Criterion
Achievements in CILOs

Excellent
(A+, A, A-) High

Good
(B+, B) Significant

Marginal
(B-, C+, C) Basic

Failure
(F) Not even reaching marginal levels

Additional Information for AR

Constructive Alignment with Programme Outcomes

PILO	How the course contribute to the specific PILO(s)
1,2,3	Students explore advanced computational modeling of physiological/neural systems, evaluating current research and applying engineering principles to complex biological systems.
4,5	Projects and case studies involve solving real-world problems, developing models for physiological/neural systems, preparing for innovation in biomedical applications.
6	Project presentations develop professional communication abilities.

Part III Other Information

Keyword Syllabus

Foundations of Physiological Modeling
Advanced mathematical techniques; computational methods; introduction to physiological control systems.

Electrical Analogs in Physiological Systems
Electrical analog of cardiovascular model; linear model of respiratory mechanics; linear model of muscle mechanics.

Physiological Control Systems
Cardiovascular control mechanisms; respiratory control systems; system integration and stability in cardiorespiratory networks; modeling closed-loop systems.

Neuronal Dynamics and Signaling
Hodgkin-Huxley model; cable theory, compartmental modelling; synaptic transmission models; neuronal networks, population dynamics.

Visual System Modeling
Retinal and cortical processing; color vision; object recognition; eye movement, visual attention.

Auditory System Modeling
Peripheral processing; central auditory processing; sound localization, spatial hearing models.

Brain Networks and Neural Interfaces
Large-scale neural network; brain connectivity; fMRI and EEG/MEG signals; brain-computer interfaces.

Reading List

Compulsory Readings

	Title
1	Michael C. K. Khoo, Physiological Control Systems: Analysis, Simulation and Control .2nd ed., Wiley-IEEE Press, 2018.
2	Paul Miller, An Introductory Course in Computational Neuroscience, MIT Press, 2018.

Additional Readings

	Title
1	Archilles J. Pappano & Withrow Gil Wier, Cardiovascular Physiology, 11th ed., Elsevier, 2018.
2	John B. West & Andrew M. Luks, West's Respiratory Physiology, 11th ed., LWW, 2020.
3	Eric R. Kandel et al., Principles of Neural Science, McGraw Hill, 2021.
4	Peter Dayan & Laurence F. Abbott, Theoretical Neuroscience: Computational and Mathematical Modeling of Neural Systems, 2005.
5	Mark. F. Bear, Barry W. Connors, and Michael A. Paradiso, Neuroscience: Exploring the Brain, 4th ed., Jones & Bartlett Learning, 2020.
6	Robert Rosenbaum, Modeling Neural Circuits Made Simple with Python, MIT Press, 2024
7	Pascal Wallisch et al., MATLAB for Neuroscientists: An Introduction to Scientific Computing in MATLAB, 2nd ed., Academic Press, 2013.